RESONANT SHOCK COMPACTION FOR COAL COMBUSTION PRODUCT UTILIZATION

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INTRODUCTION

At the University of Denver Environmental Materials Laboratory, Resonant Shock Compaction (RSC) has been employed in numerous laboratory tests to compact high-carbon Class F fly ash, bottom ash, and binders into solid dense specimens. Laboratory specimens containing up to 100% ash have passed several ASTM concrete and masonry standard tests for compressive strength, water absorption, freeze-thaw durability, and aggregate durability (Table 1). RSC holds considerable promise as a means of successfully converting large volumes of high-carbon ash into construction materials.

The RSC technology is a high-g particle packing and forming process that has been licensed for ten years to commercially manufacture refractories weighing up to 5000 pounds. The Public Service Company of Colorado has funded a program at the University of Denver to develop applications of RSC to forming high-carbon Class F fly ash and bottom ash into value-added blocks and panels to construct sound barriers, retaining walls, pond liners, and tilt-up building panels. The Environmental Materials Laboratory is providing test facilities to study RSC process dynamics and product characteristics.

Typically, high-carbon test specimens formed by the RSC process have a compressive strength of 2000 to 5000 psi. Even specimens made from stoker fired ash containing 30% LOI measured 2500 psi. RSC is a robust technology that is tolerant of a wide range of carbon, calcium oxide, and calcium sulfate.

The RSC machine at the Environmental Materials Laboratory is a commercial sized unit capable of compacting 2000 pound parts. Laboratory test specimens are nominally 10 pounds but a mold to make 500 to 1000 pound panels has been designed. Large ash-based blocks and panels will be made for field testing.

SUMMARY

Based upon Resonant Shock Compaction of Public Service Company of Colorado Cherokee Plant Class F fly ash and bottom ash this past year, it appears that the RSC technology can compact high-carbon ash into construction blocks, panels, or aggregate that pass many ASTM concrete and masonry strength and durability standards. These standards include compressive strength of 3000 to 5000 psi, sodium sulfate aggregate durability,

face fired masonry water absorption, and freeze-thaw 300 cycle tests. These tests were performed by an ASTM certified commercial laboratory.

Papers at the last three **DOE FETC Conferences on Unburned Carbonaceous Material on Utility Fly Ash** reported that the highest valued ash utilization (cement admixture) is "at risk" because low NOx combustion technology often increases ash carbon content above the ASTM 618 limit of 6%, and the industry preference for 3% or lower. There is considerable effort underway to modify combustion processes to reduce ash carbon content and other efforts to increase alternative high-volume use options for high-carbon ash such as structural fill, agricultural soil amendments, and mine stabilization. Ash use is also limited by transportation cost to market and seasonal demand by the construction industry. Reduced ash use in concrete results in increased cement consumption and an associated one ton of CO2 for each ton of cement clinker produced.

Current research and development is focused on PSCo Cherokee Class F fly ash containing sodium carbonate flue gas conditioning agents and bottom ash, Valmont Class F fly ash and bottom ash, Comanche Class C fly ash, and Hayden bottom ash mixed with fly ash which has been conditioned with limestone (flue gas desulfurization conditioned fly ash). Other tests include similar ashes, high carbon stoker ash (30% LOI), and circulating fluid bed ash containing highly reactive residual calcined calcium oxide with calcium sulfate.

The RSC market goal is to provide an alternative high-volume, high-valued product utilization of coal combustion products in partnership with electric utilities, ash brokers, construction companies, and manufacturers of concrete blocks, panels, and bricks. Acceptance of RSC ash-based construction materials is predicated upon successfully demonstrating the strength and durability of these products and obtaining the construction industry certifications from the International Conference of Building Officials, National Evaluation Service (ICBO NES).

Large blocks and panels will be made at the Environmental Materials Laboratory for testing in real applications. A transportable commercial plant will be built. Marketing studies have been performed by MBA students at the University of Denver Daniels School of Business. A preliminary conceptual design including capital and operating costs has been completed. Projected capital and operating costs are quite low.

Several electric utilities, environmental contractors, construction companies, and block manufacturers are participating in evaluation of the RSC technology to convert ash into construction blocks and panels. Waste clay and mine tailings are also being tested independently and in combination with ash. Specific products of interest to these parties are low cost highway sound barriers, retaining walls. pond liners, and tilt-up building walls. Test specimens containing

greater than 50% bottom ash can be sawed, screwed, and nailed like wood.

The University of Denver, Environmental Materials Laboratory, RSC LLC, and several electric utilities, are continuing studies to understand the unique properties of the RSC formed ash-based products. High-carbon ash formed into high strength products by the RSC process appear to be stronger than conventionally formed high-carbon ash products. RSC particle packing and high-g compaction of fly ash, bottom ash, and binder only requires about 10% water. This bonding process is being studied.

Acoustic velocity absorption and scanning electron microscopy have been used to measure ash and RSC product characteristics. A scanning optical microscopy densitometer system has been developed to measure product porosity. Acoustic velocity will be measured to correlate with product integrity. Differential scanning calorimetry and wide line proton nuclear magnetic resonance can provide information on ash-cement hydration.

The US Department of Energy has funded similar studies of the RSC technology at the University of Denver, Environmental Materials Laboratory to compact and stabilize radioactive and heavy metal contaminated soils. These studies have been conducted in cooperation with the DOE Rocky Flats Environmental Test Site, the DOE Argonne National Laboratories, and the DOE Mixed Waste Focus Area. Preliminary results have shown that RSC compacted soils have lower toxicity leach rates than other methods.

Table 1. RSC Specimen Performance vs Test Standards

PRODUCT	RSC	Standard	Compressive	Absorption		Freeze-Thaw (Alternative)		
	Results	Test	Strength		Saturation	ASTM C 67	ASTM C 666	ASTM C 1262
			(Average)	Cold Water	Coefficient	<16 F - <90 F	0F - 40 F	5F - 70F
			PSI	Max %	Max	50 Cycles	300 Cycles	100-200 Cycles
CONSTRUCTION								
MATERIALS								
Building Brick	Passed	ASTM C 62 - 92c	SW 3000	17	0.78	50	Not Applicable	New Test
	Passed		MW 2500	22	0.88	50	Not Applicable	New Test
	Passed		NW 1500	No limit		50	Not Applicable	New Test
Soundness of Aggregate	Passed	ASTM C 88						
Sodium Sulfate <16% loss								
Facing Brick	Passed	ASTM C 216 - 97	SW 3000	17	0.78	50	Not Applicable	New Test
	Passed		MW 2500	22	0.88	50	Not Applicable	New Test
Pedestrian and Light	Passed	ASTM C 902-95	SX 8000	8	0.78	50	Not Applicable	New Test
Traffic Paving Brick	Passed		MX 3000	14	No limit	50	Not Applicable	New Test
	Passed		NX 3000	No limit	No limit			
Solid Concrete	Passed	ASTM C 936 - 82	8000	5		50	Not Applicable	New Test
Interlocking Paving Units								
Heavy Vehicular Paving	Passed	ASTM C 1272 - 95	R 8000	6		50	Not Applicable	New Test
Bricks				6				
Concrete Grid Paving	Passed	ASTM C 1319 - 95	5000	10 lb/cu ft		50	Not Applicable	New Test
Units								
Concrete Block Facing	Passed	CDOT Section 504	4500			No Freeze-Thaw Requirement		
MSE Walls								
WASTE DISPOSAL								
DOE RCRA Metals	Passed	EPA TCLP	3000				150	
Solidification/Stabilization								